RESEARCH HIGHLIGHTS

Technical Series 01-103

ENERGY USE PATTERNS IN OFF-GRID HOUSES

Introduction

This project is a survey of twelve "off-grid" households across Canada. The objective is to document off-grid energy use and lifestyle patterns to determine if there are lessons or examples of energy conservation that apply to conventional grid-connected houses. The houses in the study operate on systems using renewable energy as the primary source of electricity. These systems run the gamut from simple photovoltaic (PV) installations with diesel generator backup, to complex "hybrid" systems that use PV, wind and seasonal microhydro for power. Most of the houses in this study feature all the "mod-cons": running water, stereos, computers, fax machines, etc. People have chosen the off-grid option for several reasons: political, environmental, financial, and entrepreneurial. In every case, homeowners cited more than one of these categories when describing their choice to use a renewable energy source.

Research Program

Twelve single family dwellings which have been off-grid and occupied for at least two years prior to the study were identified in three regions: Nova Scotia, Manitoba and British Columbia. The energy source(s), the system size and the storage system as well as the possible electrical load were noted for each house. In most cases the energy used by the lights or appliances was determined by running each of them and by noting the draw on the system. In several cases, the homeowners already had the information, either from the exercise of sizing their system in the first place, or because of their familiarity with it and the usage patterns. To determine an approximate actual annual loading, homeowners were asked to estimate the hours each light and appliance was run on a daily or weekly basis. Where the water heating source, typically propane, was also the energy source for cooking, and in some cases, refrigeration, the kiloWatt-hour equivalent of that fuel source and the efficiencies of the appliances were calculated and added to the estimated actual annual load. The energy required for the generator was considered outside of the load generated by the household. The estimated actual annual load total was compared to the "baseload" figures described below.

The average electrical "baseload" (the amount of energy used for lights and appliances) for a standard house of the same vintage in the same province was determined, as was the energy required for water heating. Every house used wood for space heating; some included excellent passive solar heating features in their design, and some used wood and/or solar for their water-heating source. Because of the variables involved in wood heat (mix of wood, efficiency of appliances, etc.), space heating was not included in any of the loading comparisons. Estimates of off-grid system costs were obtained from each homeowner. An airtightness test was performed on 10 houses (two houses were not viable for testing because of renovations).

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Electrical System Configuration and Loading

All twelve houses have renewable energy sources as their primary source of electricity, and most of them have fossil fuel generators for backup. In most of these houses, the lighting and water pumps were the highest draws on the system. See case studies for details.

#	Location	Start-Up Year	Energy Source(s)	Rated System Size, in Watts*	Power Storage, Amp Hours	Max. Power Storage MJ (kwh)	Possible Daily Load, MJ (kwh)	Actual Daily Load, MJ (kwh)	% Battery Drain/ Day**	# Days House Can Run Off Batteries **
1	Yarmouth Co, NS	1998	Wind/PV/Gas	1,000 (5,000)	1,200	54 (15)	42 (12)	19 (5)	35-77	1-3
2	Gulf Islands, BC	1994	PV/Diesel	200 (5,000)	1,200	54 (15)	14 (4)	7 (2)	13-26	4-7
3	Gulf Islands, BC	1997	PV/MH/Wind/Gas	1,920 (3,500)	1,250	54 (15)	38 (11)	20 (6)	37-73	1-3
4	Gulf Islands, BC	1981	PV/Wind/Diesel	830 (3,500)	1,200	52 (14)	18 (5)	11 (3)	21-34	3-5
5	Gulf Islands, BC	1991	PV/MH/Propane	500 (3,500)	1,200	52 (14)	11 (3)	6 (1.6)	11-21	5-8
6	S. Manitoba	1995	PV	125	220	9 (2.5)	2 (0.5)	1 (0.3)	10-19	5-10
7	S. Manitoba	1980	PV	100	100	4 (1.1)	2 (0.5)	0.7 (0.2)	17-38	3-6
8	Antigonish Co, NS	1994	PV/Gas	420 (6,000)	1,400	61 (17)	10 (2.7)	6 (1.7)	10-16	10-6
9	Antigonish Co, NS	1997	PV/Gas	420 (3,500)	880	38 (11)	5 (2)	4 (1)	10-14	7-11
10	Belfast, PEI	1997	Wind/Grid	900 (grid)	840	36 (10)	29 (8)	22 (6)	60-80	1-2
11	Keswick Ridge, NB	1994	PV/Diesel	333 (3,500)	1,200	52 (14)	7 (2)	3 (1)	5-15	7-17
12	Eastern Shore, NS	1994	PV/Wind	900	600	26 (7)	5.8 (1.6)	2.4 (0.7)	10-22	15-10

** The bracketed numbers in column #5 "Rated System Size" are the power ratings of backup generators, in Watts.*

*** Assuming fully charged battery bank.*

Comparisons of Light and Appliance Use

The following table outlines the estimated annual actual load for electrical and non-electrical[1] appliances for each house and compares those loads to the baseloads[2] for similar houses in the same region.

House #	Estimated Actual Load, Lighting/ Appliances, MJ (kWh)	MJ (kWh) Equivalent, Non-Electrical (Not Including Wood-Burning Appliances)	Water Heating Load Included	Total Estimated Actual Load, MJ (kWh)	Average Baseload, MJ (kWh)	Difference Between Actual and Baseload, MJ (kWh)	% Reduction from Baseload
1	7,050 (1,960)	31,100 (8,640)	Y	38,150 (10,600)	49,000 (13,610)	10,850 (3,010)	22
2	2,700 (750)	20,600 (5,720)	Y*	23,300 (6,470)	33,270 (9,240)	9,970 (2,770)	30
3	7,380 (2,050)	10,180 (2,830)	N	17,560 (4,880)	24,500 (6,810)	6,940 (1,930)	28
4	4,000 (1,110)	15,330 (4,260)	N	19,330 (5,370)	26,470 (7,350)	7,140 (1,980)	27
5	2,080 (580)	21,600 (6,000)	Y	23,680 (6,580)	47,400 (13,170)	23,720 (6,590)	50
6	330 (90)		N	330 (90)	20,450 (5,680)	20,120 (5,590)	98
7	260 (70)		N	260 (70)	20,850 (5,790)	20,580 (5,720)	99
8	2,160 (600)	38,960 (10,820)	Y	41,120 (11,420)	49,000 (13,610)	7,880 (2,190)	16
9	1,340 (370)	22,800 (6,330)	Y	24,140 (6,710)	49,000 (13,610)	24,860 (6,910)	51
10	7,810 (2,170)	13,570 (3,770)	Y	21,380 (5,940)	49,000 (13,610)	27,620 (7,670)	56
11	1,090 (300)		N	1,090 (300)	21,780 (6,050)	20,690 (5,750)	94
12	820 (230)	5,690 (1,580)	N**	6,510 (1,810)	24,500 (6,810)	17,990 (5,000)	73
Average	3,210 (890)	19,820 (5,510)		18,080 (5,020)	34,850 (9,680)	16,770 (4,660)	48
Range	260 – 7,810	5,680 – 38,960		260 – 41,120	20,450 –49,000	6,940 – 24,870	16 – 99
	(70 – 2,170)	(1,580 – 10,820		(70 – 11,420)	(5,680 –13,610)	(1,930 – 6,910)	

* *An estimated 25% of both the water heat and cooking fuel for this house is derived from an airtight cookstove with a water jacket. The estimated annual baseload reflects a reduction of 25% in energy use to compensate for this.*

***Although the hot water in this house is heated using the propane stove, the amount of hot water used is negligible, as it is only required for dishwashing and occasional bathing (homeowner uses "solar shower" water bag) for one person. As a result, the water-heating load was not included for this house.*

[1] *"Non-electrical" appliances (other than wood burning appliances) in use in the study houses are propane-fired. Assumptions about propane use: 26,417 available Btu per litre. Usage figures based on information from Superior Propane (Kentville, NS office) # litres used by appliance annually (as a proportion of total purchased litres where several appliances are used) * efficiency of appliance * 0.0002929 = kWh equivalent. This figure divided by a factor of 3.6 gives the MJ equivalent.*

[2] *Baseload figures are derived from "Home Energy Retrofit in Canada: Overview and Opportunities"; NRCan & CMHC, March 1994. ISBN 3662-22198-2*

Reasons for Going Off-grid/Lifestyle and Energy Use Pattern

Reasons for going off-grid ranged from the practical (remote location) to the environmental/political (renewable energy). Of the 12 installations, eight were at sites sufficiently remote to warrant an off-grid installation based on a straight cost comparison between going off-grid and bringing the utility line to the site. Four sites were within reasonable distance of existing power lines, but the homeowners' choice to be off-grid was directed in part by long-term savings versus rising conventional energy costs, or for environmental/political reasons. Three of these four non-remote locations are owned by individuals who are "in the business" of consulting on renewable energy projects, or selling the systems and components themselves, and had a vested interest in living off-grid, as well as being "presold" on the concept. The last non-remote home was designed to be off-grid because the homeowner is a seasonal worker who wanted minimal operating costs during his downtimes (as well as simply not wanting to "give money away" to the local utility). Most of the homeowners named concerns over environmental damage from fossil fuel generation processes as a prime-motivating factor in choosing to be off-grid, and all homeowners considered the initial cost of the systems as "pre-buying" power, especially those in remote locations.

Lifestyle and energy use patterns included timing activities that require major draws on the system (washing machines, vacuums, etc.) with either optimum energy gathering times, or when the generator is run (only in houses where the generator runs regularly). Another pattern noted was shifting the activities so that only one major draw occurred on one day, helping to "balance" the energy required for these activities over several days.

Many homeowners noted that their connection with the weather and the seasons had become more obvious or important after going off-grid, an awareness of these factors being crucial to how their household energy use was being replenished or depleted. For some, this awareness has increased their personal commitment to environmental issues.

Implications of Energy Use Patterns in Off-grid Houses

It is difficult to quantify energy use with precision in this study, because there is a mix of energy sources that cannot be metered, such as wood and propane and efficiencies of older appliances etc. All figures should be taken as close proximations. The key issue in the study is the fact that these homeowners, due to the limits of their energy supply, have easily modified or re-arranged their energy use patterns to adjust to that supply. In some cases, the degree to which homeowners have chosen to reduce their energy consumption would be extremely uncomfortable and untenable for most people accustomed to a typical North American "standard of living". However, there are several examples of more or less typical house-hold lighting and appliance mixes that are significantly below the baseload figure.

House 1 and House 10 were designed with larger systems that reflect the mix of appliances and lighting typically found in grid-connected houses (including full-size electric refrigerators and freezers, as well as computers, fax machines and TVs. Even so, these houses show a reduction in energy use of 22% and 24% respectively for lighting, appliances and hot water use (hot water in both houses supplied by propane).

House 6 and House 7 are examples of more "bare-bone" systems, which suit the lifestyle needs of a small cross-section of rural homeowners. House 11, while not as spartan as Houses 6 and 7, is still comparable to a specific rural lifestyle. However, all three houses, with an average reduction of over 90% in energy use, offer some excellent insights into efficient and effective use of energy, especially in cost-effective refrigeration possibilities. The total system in House 12 is not powerful enough to run a hairdryer, yet the energy needs of a family of four have been handily met in the past – showing another excellent example of conscientious energy use.

In total, an average energy use reduction from the typical baseload is about 44%. Of the six houses with propane or electric refrigerators, the average reduction is closer to 30%, and of the six houses without refrigerators, the average reduction is around 70%, showing the impact of these appliances on energy requirements.

One of the big-ticket items in terms of energy use is refrigeration. All bemoaned the fact that refrigerators of any ilk were too expensive both to buy and to run. There were several solutions to refrigeration needs. Houses 1 and 10 have typical electric refrigerators, while Houses 3, 4, and 5 have propane refrigerators. Apparently, new propane units are not as good as old ones for maintenance and longevity. The most energy efficient–and highly usable, easily adaptable systems–were found in Houses 6, 7 and 8. Houses 6 and 7 feature vented walk-in cold rooms, while House 8 has a "California cooler", a thermally isolated locker with a cold air vent running up from the crawlspace and a top vent to create a cold air "chimney". This arrangement brings consistent cool air to food products

which need to be kept cool (for example dairy, fragile greens, etc.), with minimal or no energy use. Houses 8, 9 and 12 had chest coolers, the 12-volt direct current (VDC) type that can be placed in a car and plugged into the lighter socket. These are typically kept in a non-heated room or a basement and not plugged in unless the weather is very hot, as they cycle on and off constantly when plugged in. Freezers were not found in any houses but House 10, which had two. In terms of energy efficiency, freezers are a fairly constant draw, and add dramatically to the cost of an off-grid system, as they result in higher overall loading. However, super energy efficient models such as the "Vestfrost ConServe", draw one-third of the energy of typical freezers (45 W versus 125W, in House 10). Some homeowners share space in a neighbour's freezer, or a community freezer.

Adequate, energy efficient refrigeration was the biggest issue for all houses, along with finding a decent AC water pump that doesn't have a huge amount of startup surge. Electro-magnetic coupled AC motors offer a great boon to energy efficient operation, but are costly and difficult to find, as far as the homeowners in the study are concerned. Other issues surrounding "odd" appliances/ motors and lighting fixtures are: cost to purchase, ease of installation, ease of repair and maintenance and availability of parts.

In terms of water heating, propane or coils/jackets off woodstoves were the norm. One major issue that came up in terms of energy use was the thermal coil ignition for new propane appliances. It is difficult to time the big loads with water heating cycles so as to not blast the inverter. This is especially true for the thermal coils in propane ovens, which cycle on and off constantly through a baking or roasting period.

There are two elements that are economically discordant: compact fluorescent lighting costs have not decreased in the last decade, while the market share of these fixtures has risen exponentially. The same applies to PV panels: the price point remains similar to that of 10 years ago, even though the market has boomed (these are still "specialized" or niche markets, obviously, but cost is probably one of the reasons why they remain so). If the initial costs came down, these items would be more utilized, and more obviously feasible to install. As it is, the manufacturers are, as one homeowner said "just putting my energy savings into their back pocket".

The following energy saving themes echoed throughout the interviews:

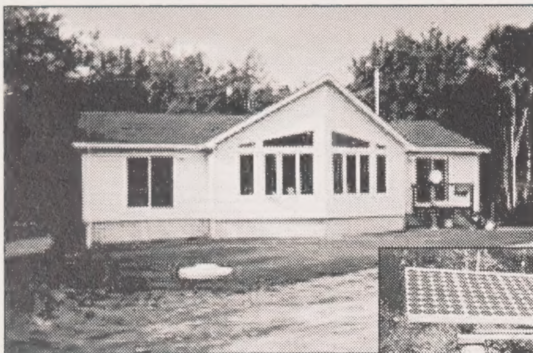
Lighting

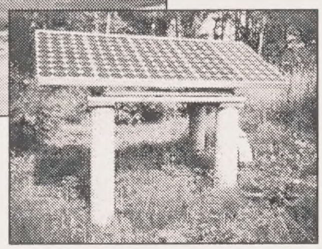
1. Lights should be turned off when they are not in use.
2. Task lighting means lower wattage, as the light can be closer to the work surface.
3. Having the outside of the house lit up all night is a wasteful use of energy, and you can't see the stars very well, either.
4. Work or study areas set close to S or SW/SE windows increase daylighting in those high-use areas.
5. "Lightpipes" or "suntubes" in darker work areas or commonly used rooms increase the overall daylighting.
6. Compact fluorescent light fixtures should be used adequately: their life cycle and efficiency are reduced dramatically when they are turned on and off constantly. They should be in places such as hallways, kitchens, stairwells, exterior fixtures, where they are going to be turned on and left on for one- or two-hour stretches.

Appliances

1. Appliances should be unplugged when not in use; don't rely on digital clocks or timers in every room.
2. It is important to buy the most energy efficient appliances you can afford (ideally those without digital clocks or timers).
3. The overall system can be smaller if high-energy draws can be staggered (i.e. don't do the washing while vacuuming), or timed so these appliances are used on clear days or when the generator is running (for battery equalization, etc.). This doesn't affect general grid connected homeowners, but it does have an impact on lifestyle patterns for those who are on time-of-use programs.
4. More efficient sources of energy should be used where possible. Avoid large thermal resistance loads.
5. Before you buy, ask yourself: Do I really need another gadget?

Energy Use Patterns in Off-Grid Houses – Case Study #1 :Yarmouth County , NS





House Description

A 16 x 8 m (52 x 26 ft.) bungalow with full basement, this energy efficient "package" house was built in 1998 for a family of four (two grown children are now part-time residents). The house takes advantage of good passive solar orientation and of a well-treed area to the north to reduce the impact of cold winter winds. An airtight stove (3 cords wood/yr) augments the solar space heating.

Thermal Envelope Summary

AC/H@50 Pa: 2.77
Walls: 2x6 framing w/RSI 3.5 (R20) (bare conc. basement. walls, no ins. @ slab)
Ceilings: RSI 7 (R40)
Windows: low-E, argon fill, insulating spacers
Doors: steel polyurethane core

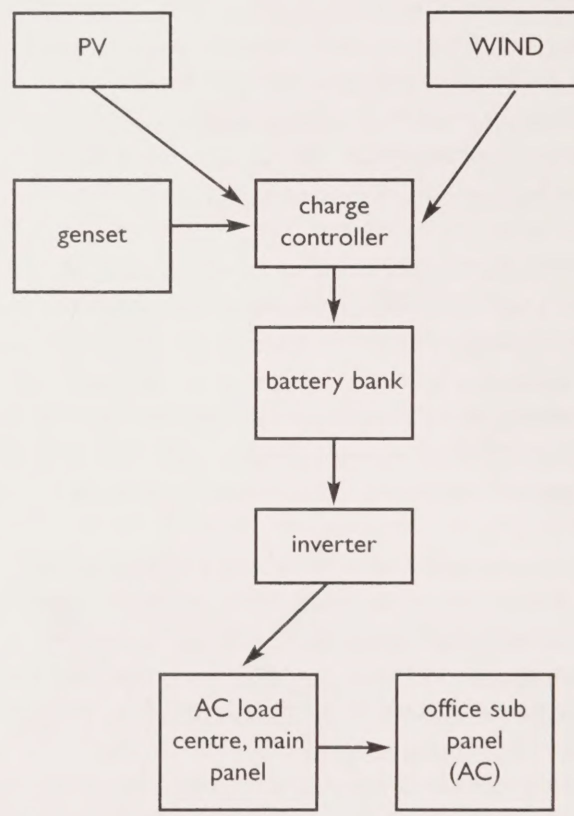
System Description

Power is supplied by a 300 W PV array and an Air 303-12 wind generator. A 5 kW gas generator is used as backup. Energy is stored in a bank of 10, T2200 golf-cart type batteries, wired to produce 12 VDC (1200 Ah). A Trace DR2412 modified sine wave Inverter/Charger is used to produce 120 VAC throughout the house (there are no DC loads). The cost to install the system was $15,000 CAD.

System Performance

The load on the system includes lighting, refrigerator, water pump, vacuum, washing machine, computer, fax machine, 26" TV with satellite system and several small appliances. The total possible daily load on the system is approximately 42 MJ (12 kWh), while the actual load is estimated to be 19 MJ (5 kWh). Propane is the energy source for water heat, clothes drying and cooking. Approximately 1470 L of propane is purchased annually. The 5 kW genset, which is housed in a small shed to the west of the house, is run an average of 1,092 hours, providing 5,460 kWh of power for the house. The genset has a remote start mechanism installed for convenience.

Annually, the actual electrical use in this house is about 7,050 MJ (1,960 kWh). When the kWh equivalent of the propane appliances is included in the actual energy use in this house, the figure is approximately 38,150 MJ (10,600 kWh). The average annual lighting and appliance energy use for vintage house in Nova Scotia is 24,500 MJ (6,810 kWh). Water heating accounts for another 24,500 MJ (6,810 kWh)[1], for a total of 49,000 MJ (13,620kWh). There is a difference of 10,850 MJ (3,010 kWh), for a 22% reduction. These figures do not include space heating.



Notes From Homeowner @ System Operation:
Windbreak @ N of house is interfering with the wind generator, the height is to be increased from 6.7 m to 15 m (22 to 50 ft.). The solar array was recently put on turntable to see if daily output can be increased. Another five panels are to be added to the system to reduce the use of the genset, which is currently run about three hours every evening.

[1] *Home Energy Retrofit in Canada: Overview and Opportunities; NRCan, CMHC, March 1994 ISBN 0662-22198-2*

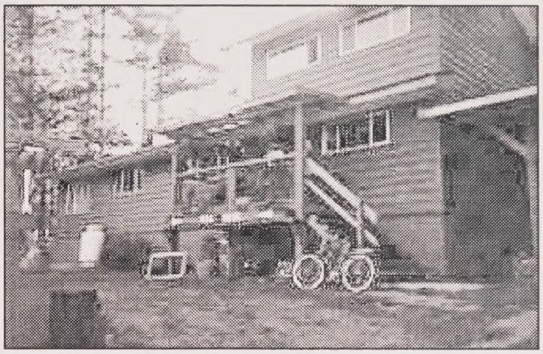
Homeowner's reasons for going off-grid:

As part of the homeowner's business, he felt it was necessary to show a "normal" house with an off-grid system, even though the cost of grid connection on this site was minimal. Homeowner has been interested in wind and PV since the 1970s, with a focus on PV for these reasons: no moving parts, quiet, minimal maintenance. The downside of PV is the toxic materials used in panels, and their susceptibility to radiation damage ("browning" or "mirroring"). Small-scale residential wind installations are typically high maintenance and site specific. Homeowner would not have recommended wind generator for this site for a client, but he had one in stock and wanted to show it to potential clients.

Homeowner's observations on living off-grid and energy use patterns:

- It is difficult to find new gas appliances without thermal coil ignition, which creates a large draw on the system.
- Wired-in smoke detectors can overheat or short out due to the modified sine wave of the inverter.
- With modified sine wave inverters, any digital clock or timer that takes its signal from the utility 60 hz cycle will not tell proper time, and any appliance that runs with an AC motor is noticeably louder (microwave, ceiling fan, etc.) in operation. Computer, phone/fax and office lights are all on a separate inverter and sub panel with an impulse phase correction that prevents the computer from rebooting.
- Laundry is done when the generator is on, or on a clear day. It is possible to complete two or three loads at a time this way.
- It is important to install appliances, lights and system components that are standard, replaceable and repairable.
- Microwave cooking with modified sine wave inverter takes twice as long because the microwave is designed for peak power of 160 VAC on demand.

Energy Use Patterns in Off-Grid Houses – Case Study #2: Gulf Islands, BC



House Description

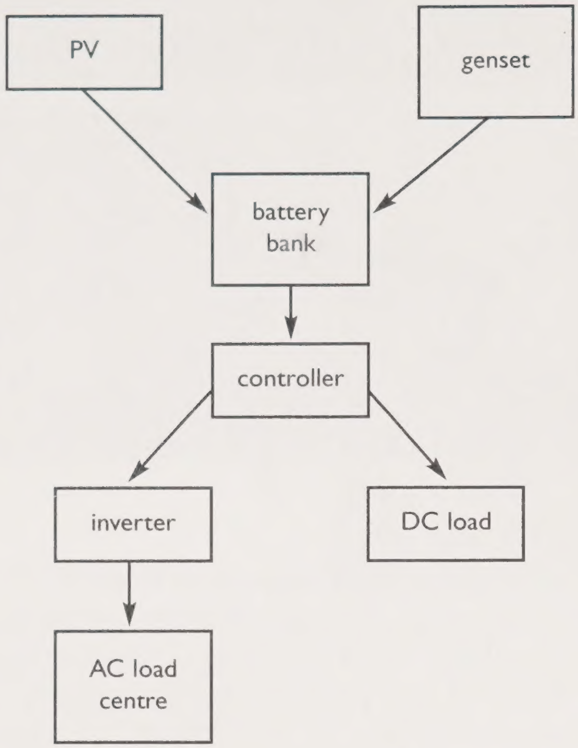
A 17.7 x 7.3 m (58 x 24 ft.) bungalow on an open crawlspace with a 5.5 x 7.3 m (18 x 24 ft.) second storey addition. The house was built in 1960 and barged to its new island site in 1981 as a retirement home for a couple. The primary axis is N-S, with view windows to the west. A wood stove and a cookstove (9 cords softwood/yr) heat the house.

Thermal Envelope Summary

AC/H@50 Pa: 17.28
Walls: 2x4 framing w/RSI 2.1 (R12) (+/- 25% crawlspace RSI 1.4/R8)
Ceilings: RSI 2.1 (R12)
Windows: single pane, sashless sliders, thermopane patio doors and one upper window
Doors: solid wood with storm door

System Description

The power is supplied by a 200 W output PV array (4-50 W panels) which was installed in 1994. A 5 kW diesel generator is used as backup. Energy is stored in a bank of 10, Canadian National "Performer" batteries, wired to produce 12 VDC (1200 Ah). A Trace DR2401 Inverter/Charger is used to produce 120 VAC. The original power system to this house was the 12 VDC diesel genset with propane and kerosene for refrigeration, cooking and some lighting. The genset was kept to backup the PV system. The original wiring in the house was for the 12 V genset system. After the PV was installed, wiring for new AC loads was added. The cost of the system (with the genset system) was $7,000 CAD.



System Performance

The load on the system includes lighting, water pump, vacuum, washing, machine dishwasher microwave, computer, two small TVs (AC/DC) and several small appliances, as well as an air compressor, table saw and radial arm saw in the workshop. The total possible daily load on the system is approximately 14 MJ (4 kWh), while the actual load is estimated to be 7 MJ (2 kWh). Propane is the energy source for the refrigerator and range (one pilot kept on, light pilot when oven is in use), and a much-used barbeque. There is a propane clothes dryer in the house, but it is not hooked up. Approximately 870 L of propane is purchased annually. The running of the genset, which is housed in a small shed to the east of the house, has been logged since 1996. In four years, the homeowners have only required the genset to run for 540 hours, which averages to less than 1/2 hr/day. However, the typical usage pattern is periodic equalization of the batteries, which means the genset is often not used for months at a time, depending on the season.

The actual electrical use in this house is about 2,700 MJ (750 kWh) annually. When the kWh equivalent of the propane appliances is included in the actual energy use for this house, the figure is approximately 23,300 MJ (6,470 kWh). The average annual lighting and appliance use for this vintage house in British Columbia (1981) is 21,450 MJ (5,960 kWh), with water heating adding another 22,900 MJ (6,360 kWh). It is estimated that wood heat accounts for 25% of cooking and water heating. Allowing for a corresponding reduction in baseloads, the total average annual baseload is 33,270 MJ (9,240 kWh). There is a difference of 9,970 MJ (2,770 kWh), for a 30% reduction. These figures do not include space heating.

Notes From Homeowner @ System Operation:
Two "sunpipes" were installed in the kitchen (which is on the east face of the house) to increase the daylighting potential in the afternoon/evening. Initially, the cooking was done on the woodstove and in a large microwave. However, the owners found that the microwave was noisy and the inverter didn't supply enough power to the microwave. A propane range was installed and the microwave use reduced. The battery bank is typically charged before noon on clear days, and the homeowners switch over to using just the available PV when this happens.

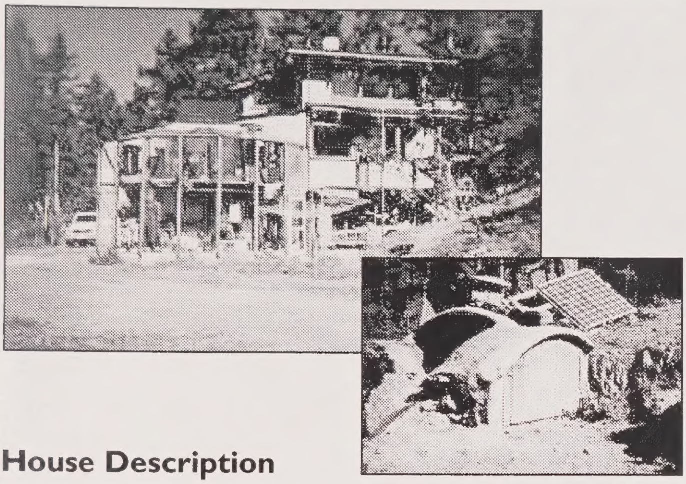
Homeowners' reasons for going off-grid:

This is a retirement home. The homeowners had bought the diesel genset as the affordable, convenient option. Their son gave them the PV system. The homeowners enjoy the quiet operation of the PV system and the reduced fuel costs associated with using renewable energy.

Homeowners' observations on living off-grid and energy use patterns:

- With modified sine wave inverters, any appliance that runs with an AC motor is noticeably louder (microwave, ceiling fan, etc.) in operation.
- Newer propane fridges don't have the longevity nor maintenance-free operation that older models offer.
- Laundry is done on a clear day and hung out to dry.
- Living off-grid has emphasized the need to turn off lights and unplug appliances when they are not being used. Original light fixtures are 12 VDC, all 120 VAC fixtures are low wattage incandescent or compact fluorescent. Visitors are not aware of power limitations, and visiting family or friends who are grid connected is quite a different experience: grandchildren wonder why the homeowners always turn out lights and unplug things wherever they go.

Energy Use Patterns in Off-Grid Houses – Case Study #3 : Gulf Islands, BC



House Description

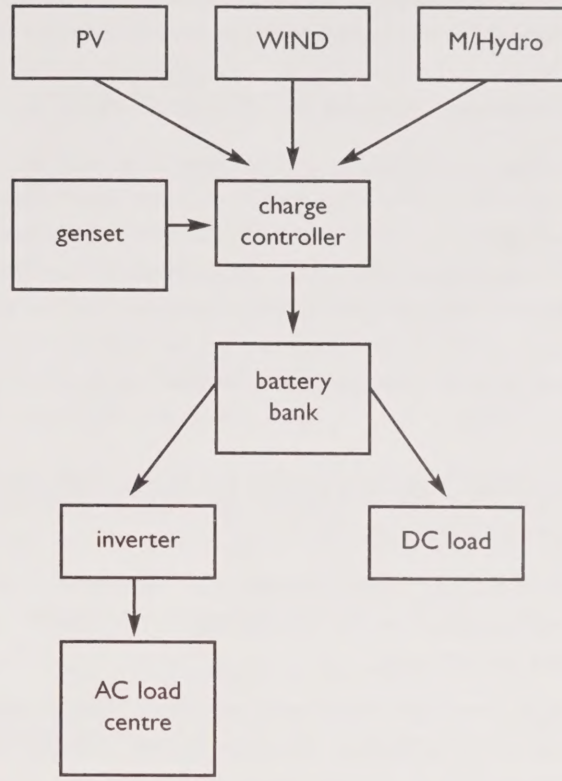
A two-storey 7.6 x 15.2 m (25 x 50 ft.) house with walkout basement. The family of four moved in 1997. A 7-sided two-storey passive solar greenhouse wrapped around the SE corner is the main source of space heating. A vacuum tube collector and tank with integral heat coil supply most of the hot water. A combination wood furnace with water coil and cookstove built around a massive central chimney heat the house and the water (3 cords wood/yr) when there isn't enough solar gain. The high mass construction includes a 100 mm concrete slab on the lower floor and 50 mm concrete overpour on the main floor. The lower walls and north facing stairwell are built of stone with an interior insulated stud wall. The remaining walls are standard 2x6 framing.

Thermal Envelope Summary

AC/H@50 Pa: n/a, as one window and a door were not in place
Walls: lower stone walls w/vermiculite, RSI 2.4 – 3.2 (R14-18), upper walls 2x6 framing, RSI 3.5 (R20),
Ceilings: RSI 3.5 (R20)
Windows: thermopanes in wood frames
Doors: solid wood

System Description

The power is supplied by a 620 W output PV array (8-60 W and 4-35 W panels); a 1,000 W Whisperlite wind generator and a 25 W microhydro system which runs seasonally (November through May) from a pond overflow. A 3.5k W gas generator acts as backup. Energy is stored in a bank of 6, P23 golf cart batteries, wired to produce 12 VDC (1,250 Ah). A Brutus pure sine inverter/charger is used to produce 120 VAC. The lights in this house are all 12 VDC fixtures, as is the fridge. The remainder of the wiring is for 120 VAC appliances. The system cost $10,000 CAD to install.



System Performance

The load on the system includes 12 VDC lighting and fridge, 120 VAC water pump, built-in vacuum, an energy efficient front-loading washing machine, microwave, two computers (one PC and one laptop), a fax machine, a stereo, a TV, an air cleaner (Bionaire type) and several small kitchen appliances as well as music equipment in the studio. The total possible daily load on the system is approximately 38 MJ (11 kWh), while the actual load is estimated to be 20 MJ (6 kWh). Propane fuels the cooktop and oven. Approximately 250 L of propane is purchased annually. The genset, which is housed in a small shed to the north of the house, is run once a week for one to four hours (approx. 4.5 L gas @ 4 hrs). Clothes washing, vacuuming, flour grinding or other high-load activities are done when the generator is on.

The actual electrical use in this house is about 7,380 MJ (2,050 kWh) annually. When the kWh equivalent of the propane appliances is included in the actual energy use for this house, the figure is approximately 17,560 MJ (4,880 kWh). The average annual lighting and appliance use for this vintage house in British Columbia is 24,500 MJ (6,810 kWh). There is a difference of 6,940 MJ (1,930 kWh), a reduction of 28%. These figures do not include space or water heating.

Notes From Homeowner @ System Operation:
The installation of the PV on the roof has turned out to be awkward for maintenance. Another two 75 W panels are to be installed within the coming year.

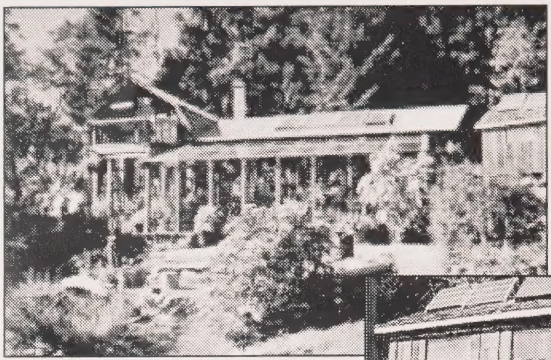
Homeowners' reasons for going off-grid:

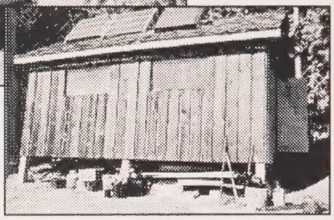
Homeowners wanted to live on this remote island, it was never an option to have a generator "plunking away". There was a long-standing desire to live off-grid "as if we were on grid". The result is an interesting juxtaposition of low-tech and high-tech solutions (passive solar and wood space and water heating with PV/wind/microhydro system; low-tech microhydro system built specifically for the site; modified 12 V fridge on timer).

Homeowners' observations on living off-grid and energy use patterns:

- Living off-grid has emphasized the need to turn off lights and unplug appliances. 12 VDC lighting is much more efficient use of power.
- Gas appliances (cooktop/oven) have low AC startup draw too small for the inverter to detect. Research has found no new "non-load" gas cooktop/ovens.
- Insurance companies don't like houses heated with wood, and want a guarantee of 24 hour, 100A electrical service or the rates are incredibly high. The phenomenon of "24/7" electricity supply is relatively new to the world in general, yet it has become the norm.
- Homeowners had a mishap with a housesitter and a homemade charge controller, where the shunt failed in open position and drained the batteries completely. Seven years later, the solar array (due to a manufacturing defect) and the same batteries failed at the same time. There was no problem replacing the panels from the manufacturer and new batteries were purchased. The lesson learned was: a good controller is indispensable, and roof-top mounted panels (whether PV or collectors for a water heating system) are difficult to get at for repair, maintenance or replacement.
- When planning to be off-grid, you have to put more emphasis on the infrastructure of the house (for example, dual wiring for 12 VDC lights and 120 VAC appliances). These homeowners look at their off-grid installation as "prepaid" electrical bills.
- When installing a PV system, put in as many panels in your array as you can afford, and build-in room for more.

Energy Use Patterns in Off-Grid Houses – Case Study #4: Gulf Islands, BC





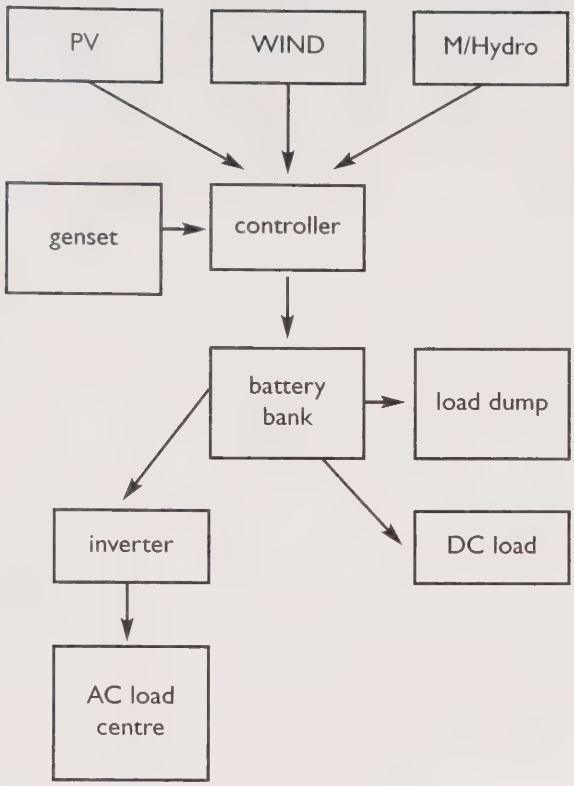
House Description

Originally a 1 1/2 storey 4.6 x 7.6 m (15 x 25 ft.) float home, in 1980, this was converted into a house on a crawlspace foundation. A 7.3 x 6.7 m (24 x 22 ft.) single storey addition on an open crawlspace was built on the SW side of the original structure. A 3.7 x 7.3 m (12 x 24 ft.) greenhouse was built onto the SE face of the addition. An unheated porch area buffers the NW side of the house. The site has good solar access and is well protected to the N and NW by trees. It was chosen for the wind/water/PV potential. An airtight cookstove provides cooking, space and water heat (5 cords wood/year), with a drain down solar DHW system used in the summer. Two adults live in the house.

Thermal Envelope Summary
AC/H@50 Pa: n/a, as float home section fragile
Walls: float home, RSI 2.1 (R12) addition, RSI 3.5 (R20)
Ceilings: float home RSI 2.1 addition, RSI 4.9
Floors: float home: RSI 3.5 (R20)
Windows: float home, single plexiglass; addition, thermopane
Doors: solid wood

System Description

The power is supplied by a 280 W output PV array (8-35 W panels); a 400 W Aerofoil 3 wind generator; and a seasonal 150 W microhydro system (runs November through May, 24 hr/day) from a source 0.4 km from house. A small generator is used for seasonal backup. Energy is stored in a bank of 12 salvaged forklift batteries, wired to produce 12 VDC (1,200 Ah). A Trace 1512 modified sine wave inverter produces 120 VAC. There is a combination of 12 VDC and 1,200 VAC wiring. The system cost approximately $7,000 CAD.



System Performance

The load on the system includes AC lights, water pump, washing machine, microwave, a computer, an answering machine, two cordless phones, a mini stereo, TV/VCR, and small kitchen appliances as well as power tools in the workshop. The total possible daily load is approximately 18 MJ (5 kWh), while the actual load is estimated to be 11 MJ (3 kWh). Propane fuels the fridge and a cooktop. There is a propane-fired hot water tank in the house, but it is not hooked up. Approximately 400 L of propane are purchased annually. The genset runs regularly September through November during the shift from solar and wind to microhydro.

The actual electrical use in this house is about 4,000 MJ (1,100 kWh) annually. This figure does not include the non-electric appliances used in the house. When the kWh equivalent of the propane appliances is included in the actual energy use for this house, the figure is approximately 19,300 MJ (5,370 kWh). The average annual lighting and appliance use for this vintage house in British Columbia is 26,470 MJ (7,350 kWh). There is a difference of 7,140 MJ (1, 980 kWh), a reduction of 27%. These figures do not include space or water heating.

Notes From Homeowner @ System Operation:
The wind generator needs to be shifted from its current position, as the trees have grown up around it. A load dump shunts power to other functions when the batteries are full. In the spring, a heating coil is run under seedbeds in the greenhouse, and in the summer a heavy-duty ceramic resistor is used (water could be heated with this extra load in the summer). Heavy-duty wire from the microhydro to the house reduces the power loss.

Homeowners' reasons for going off-grid:

One person in this household has lived off-grid for 20 years, as a conscious lifestyle choice. The other member moved into this off-grid house eight years ago.

Homeowners' observations on living off-grid and energy use patterns:

- Being off-grid raises awareness of power consumption, and how power fluctuations and different loading scenarios can stress motors, reducing their useable life. Modified sine wave inverter doesn't run such things as "Walkman" style tape recorders.
- Installing and fabricating your own module mounts, salvaging and reusing existing equipment from other installations can reduce the cost significantly.
- When the weather and the seasons generate your power, you tend to be more conscious of what's going on out there.
- Microhydro systems require water licenses. When the homeowners applied for a license for their 150 W system (which they share with another household), they couldn't get one, because the lowest listing available for a microhydro/run of river system was 1 kW, and anything below that mark is "unfeasible".
- Propane appliances such as fridges are expensive to purchase and run (approximately 1 L/day). New ones are difficult and expensive to get fixed. If the propane hot water tank was connected, the household would use 100 L of propane in 3 weeks vs. 3 months.
- A cool cupboard is a cost-effective way to store food at lower temperatures, perhaps allowing for a smaller, more efficient fridge to be installed.
- To increase the efficiency of the conventional top-loading washing machine by 40%, the homeowners removed the 120 VAC 2 speed motor and replaced it with a 90 VCD permanent magnet motor. In older model washing machines, the motors bolt in, so the retrofit is relatively easy to accomplish, but it is important to get the right pulley size, otherwise the water in the machine gets tossed so violently that it overflows the drum of the machine.

Energy Use Patterns in Off-Grid Houses – Case Study #5: Gulf Islands, BC

House Description

A 9.1 x 12.2 m (30 x 40 ft.) 1 1/2 storey house on an open crawlspace was built in 1991, on the high side of a steeply sloping south-facing site with excellent solar access and winter wind protection from tree cover at the top of the mountain. An airtight woodstove provides space heat (3 to 4 cords wood/year, unless winter holiday taken, then 2 cords, primarily arbutus) for the single occupant (and guests).

Thermal Envelope Summary
AC/H@50 Pa: 15.14
Walls: RSI 3.5 (R20)
Ceilings: RSI 3.5 (R20)
Floors: RSI 2 (approx) (R12)
Windows: thermopanes
Doors: solid wood

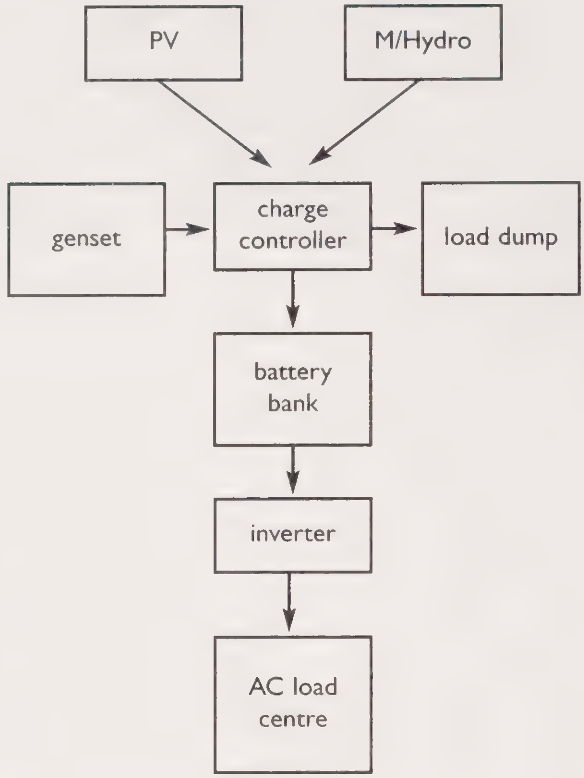
System Description

The power is supplied by a 360 W output PV array (6-60 W panels) and a seasonal 240 W microhydro system (runs November through May, 24 hr/day) from a source 0.4 km from house. A propane-converted generator is used for seasonal backup. Energy is stored in a bank of 6, 85T13 batteries, wired to produce 12 VDC (1,200 AH). An inverter produces 120 VAC, and the whole house is wired for standard AC lights and appliances. The system cost approximately $15,000 CAD.

System Performance

The load on the system includes 120 VAC lights, water pump, washing machine, vacuum cleaner, a computer, laser printer and modem (heavy use for several hours a day), a cell phone, a stereo, two radios, TV/VCR, and small kitchen appliances. The total possible daily load is approximately 11 MJ (3 kWh), while the actual load is estimated to be 6 MJ (1.6 kWh).

Propane is the energy source for the fridge, range, water heat and generator. Approximately 1,300 L of propane is purchased annually. The genset runs regularly September through November during the shift from solar to microhydro, and sometimes on winter evenings when the homeowner is working late on the computer.



The actual electrical use in this house is about 2,080 MJ (580 kWh) annually. When the kWh equivalent of the propane appliances is included in the actual energy use for this house, the figure is approximately 23,680 MJ (6,580 kWh). The average annual lighting and appliance use for this vintage house in British Columbia is 24,500 MJ (6,810 kWh). Water heating accounts for a further 22,900 MJ (6,360 kWh), for a total of 47,400 MJ (13,170 kWh). There is a difference of 23,720 MJ (6,590 kWh), a reduction of 50%. These figures do not include space heating.

Notes From Homeowner @ System Operation:
A load dump shunts excess power to two heat coils in the bathroom; grow-lights are used during the winter to absorb power as well as grow plants. The generator is also frequently required in the summer for early morning garden watering, as the sun doesn't hit the PV until mid-morning because of the surrounding trees and the slope of the hillside. Batteries are typically full by 1 p.m., year round. The only limitation is the water pump can't be run at the same time as the printer or the vacuum cleaner.

The microhydro provides continuous 20A service at the house, over 0.4 km of 110 cable from the end of the driveway, which is stepped down to 12 V for the batteries and then stepped back up again through the inverter for household use. There is a problem with the microhydro system when too much water flows down the hillside, bringing rocks with it which pile over the intake valve. The site is such that the intake valve cannot be set into a more protected area.

Homeowners' reasons for going off-grid:

Knew about PV before buying the land. Fell in love with site. Would have cost $1/2 million to bring in- grid connection. Reread Harrowsmith and gathered information from technical manuals for six months before beginning construction. Thought of using propane for lighting as well, but needed to run the computer and didn't feel comfortable with the generator for hours at a time, so went with the PV/microhydro system.

Homeowners' observations on living off-grid and energy use patterns:

- Being off-grid raises awareness of power consumption, power fluctuations and different loading scenarios (that is, can't operate pump and printer together). When your power is generated by the weather and the seasons, you tend to be more conscious of what's going on out there.

Energy Use Patterns in Off-Grid Houses – Case Study #6: Southern Manitoba

House Description

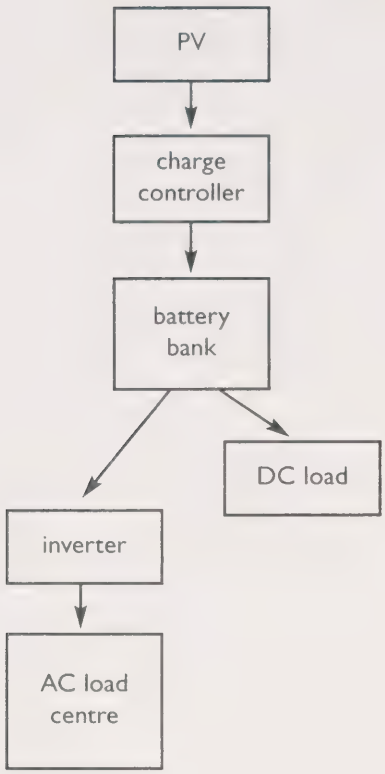
House #6 and House #7 are located on the same farm, which has seven off-grid houses, five of which are permanently occupied. All the systems on the farm are small, but very efficient.

House #6 is a 4.9 x 6.7 m (16 x 22 ft.) 1 1/2 storey house on a pole foundation built in 1995. Four people occupy the house (two are children). The house has good solar access and some protection to the north and the NW from trees and the screened porch/insulated cold room. An Enterprise cookstove provides cooking, space and water heat (4 cords wood/year). The house was built from recycled wood, the double stud walls allow 200 mm (8 in.) of fiberglass insulation. A solar cooker is also used for baking and slow cooking.

Thermal Envelope Summary
AC/H@50 Pa: 7.22
Walls: RSI 4.9 (R28)
Ceilings: RSI 5.6 (R32)
Floors: RSI 3.5 (R20)
Windows: triple pane, no openers (adjustable vents for fresh air)
Doors: solid wood

System Description

The power is supplied by a 125 W output PV array (6-40 W panels). Energy is stored in 2, 6 V golf cart batteries, wired to produce 12 VDC (220 Ah). All lighting is 12 V, several of which are site-built fixtures which use 3 W automotive bulbs. A 150 W Statpower modified sine wave inverter produces 120 VAC for a few small appliances. The system cost approximately $1,500 CAD.



System Performance

The load on the system includes 12 VDC lights, water pump, two small motors to operate the vents in the cold room, washing machine (not used much), vacuum cleaner (not used much), a cordless phone (fitted with an energy saving feature) and a stereo. Small kitchen appliances run off the inverter: blender, mixer and sewing machine. The total possible daily load is approximately 2 MJ (0.5 kWh), while the actual load is estimated to be 1 MJ (0.3 kWh).

The actual electrical use in this house is about 330 MJ (90 kWh) annually. The average annual lighting and appliance use for this vintage house in Manitoba is 20,450 MJ (5,80 kWh). There is a difference of 20,120 MJ (5, 590 kWh), a reduction of 98%. These figures do not include cooking, space or water heating.

The cold room, a large walk-in cooler/pantry which replaces a fridge, takes up the NW corner of the house. It is completely insulated and isolated from the rest of the house. It is kept at a constant temperature by a sensor that causes an exterior venting system to open when the temperature exceeds 8°C (46°F), allowing cold air in from outside until the temperature drops to 5°C (41°F). An interior venting system opens when the temperature is below 5°C, bringing warmer air from the interior of the house into the cold room. The sensor closes the interior vent when the temperature reads 8°C (46°F). The small 12 VDC motors that operate the venting system run for a few seconds at each opening/ closing sequence, drawing hardly any discernible load.

Notes From Homeowner @ System Operation:
The system is designed to carry the house through several short days of poor solar gain during the winter months, resulting in too much power for the rest of the year. The homeowner ran out of power on the original 50 W system once during a 3-week cloudy spell when one of the children was a newborn. The system was boosted with a 20-minute charge from another off-grid source on the farm. The largest load on the system is the water pump, which is the motor out of a windshield wiper assembly. This 12 V motor runs for about 1 hour a day to fill a 225-L (50 gal) container. Water is taken from this container and used in the house (heated on the cookstove) or in the garden. The summer watering needs of the garden are the largest draw on the system, matched well with the availability power from the sun.

Homeowner's reasons for going off-grid:

Homeowner chose to move from an urban environment to a rural one. The choice to be off-grid came from political and environmental convictions.

Homeowner's observations on living off-grid and energy use patterns:

- There is an adjustment to make to lower levels of light, when off-grid and no yard lights, etc.
- Pumping water and having to heat it over stove requires a large change in water consumption habits. Instead of bathing, the homeowners use a sauna.
- An indoor composting toilet system further decreases the water requirements in the household.
- Seasonal changes are more obvious as power needs go up during winter and power generation goes down.

Energy Use Patterns in Off-Grid Houses – Case Study #7: Southern Manitoba

House Description

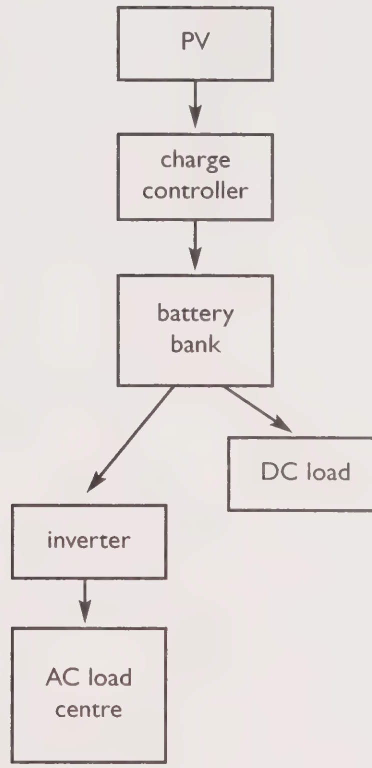
House #6 and House #7 are located on the same farm, which has seven offgrid houses, five of which are permanently occupied. All the systems on the farm are small, but very efficient.

House #7 is a 15 x 4.9 m (60 x 16 ft.) one-storey house with a sleeping loft, built on a pole foundation in 1980. The house has been occupied by one person for several years. The house has good solar access and some protection to the north. An Enterprise cookstove provides cooking, space and water heat (3 cords wood/year). The original part of the house (a 6-sided structure of approximately 28 m^2/300 sq. ft.) is 2x4 framing. The newer "wing" additions to the west (4.9 x 3.7 m/16 x 12 ft.) and the east (3.7 x 3.7 m/12 x 12 ft.) are 2x6 framing. A 4.9 x 1.2 m (16 x 4 ft.) greenhouse on the west addition helps to keep the living space comfortable, with a site-built venting system operated by a temperature sensor and a small 12 VDC motor. There is a cold room with the same operating system as House #6.

Thermal Envelope Summary
AC/H@50 Pa: 5.63
Walls: Original, RSI 2.1 (R12);
Additions, RSI 3.5 (R20)
Ceilings: RSI 3.5 (R20)
Floors: RSI 3.5 (R20)
Windows: double pane/combination
Doors: solid wood

System Description

The power is supplied by a 100 W output PV array (2-50 W panels). Energy is stored in 2, 6 V RV batteries, wired to produce 12 VDC (100 Ah). All lighting is 12 V, several of which are site-built fixtures which use 3 W automotive bulbs. A 150 W Powerstar modified sine wave inverter produces 120 VAC for a few small appliances. The system cost approximately $1,500 CAD.



System Performance

The load on the system includes 12 VDC lights, small motors to operate the venting systems in the greenhouse and cold room, as well as a fan for a food dryer in the greenhouse, a water pump and a stereo. Small appliances run off the inverter: blender, shaver, glue gun and soldering iron as does a 22 W fluorescent fixture in the "summer kitchen" (screened-in area where food is processed during harvest season). An electric lawnmower is charged off this system during the summer. A 10 Ah motorcycle battery in the summer kitchen powers the washing machine. The total possible daily load is approximately 2 MJ (0.5 kWh), while the actual load is estimated to be 0.7 MJ (0.2 kWh).

The actual electrical use in this house is about 260 MJ (70 kWh) annually. The average annual lighting and appliance use for this vintage house in Manitoba is 20,850 MJ (5,790 kWh). There is a difference of 20, 580 MJ (5,720 kWh), a 99% reduction. These figures do not include cooking, space or water heating.

Notes From Homeowner @ System Operation:
The system is designed to carry the house through several short days of poor solar gain during the winter months, resulting in too much power for the rest of the year. The largest load on the system is the water pump, which runs for two hours a day, using 30 W. Water is taken from this container and used in the house (heated on the cookstove) or in the garden. The summer watering needs of the garden are the largest draw on the system, matched well with the availability power from the sun. Sauna replaces showering or bathing.

Homeowner's reasons for going off-grid:

Homeowner chose to off-grid, simplified living because of political and environmental convictions. The homeowner is one of the original co-operants on the farm, established in the late 1970s. This system was originally on a manual tracker, but there was not enough difference in power generation to warrant the effort to move the array.

Homeowner's observations on living off-grid and energy use patterns:

- A feeling that quality of life was diminished by the proximity of loud equipment and all-night yard lights was part of a co-operative decision for the farm to remain off-grid during the mid 1980s, when 30 people were living in the community. Some members left to establish a grid-connected farm after this.
- A 960 W wind generator functions on the farm, but it is used to grind grain, not produce power, because no farm members require more power than their small household systems produce. The wind generator grinds up to 13.5kg/day.
- DC is a "friendlier" power – the low voltage poses little hazard for shock.

Energy Use Patterns in Off-Grid Houses – Case Study #8: Antigonish County, NS

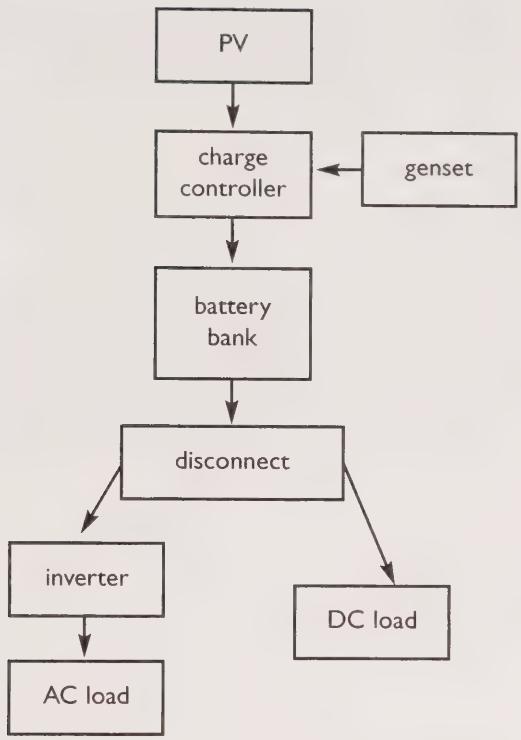
House Description

A 6.7 x 10.4 m (22 x 34 ft.) 2 1/2 storey house built on a combination basement/open crawlspace foundation. This house has been occupied by a family of five (now six) full-time since 1994. The house has reasonable SE to S solar access (concession to the view to the SE) and good protection to the north from a treed hillside. An airtight woodstove provides space heating for the whole house (4 cords wood/year). The original part of the house was constructed in 1988 as a seasonal residence, with a typical "cottage" PV system. In 1994, when the family moved in, the house and the system were as described below.

Thermal Envelope Summary
AC/H@50 Pa: 11.24 (one bedroom and loft area not finished)
Walls: 3.5 RSI (R20), double wall construction in progress to upgrade
Ceilings: RSI 4.9 (R28)
Floors: RSI 3.5 (R20)
Windows: double pane
Doors: steel polyurethane core

System Description

The power is supplied by a 420 W output PV array (4-105 W panels). Energy is stored in 6, 6 V L-16 batteries, wired to produce 12 VDC (1,400 Ah). All lighting is 12 V, including compact fluorescent, halogen and hi/low car taillight type. A Trace square wave inverter produces 120 VAC for certain appliances (washing machine, battery charger, skilsaw). A 6 kW gas generator provides backup power. The system cost approximately $10,000 CAD.



System Performance

The load on the system includes 12 VDC lights, a water pump, TV/VCR and three "personal" stereos. Small kitchen appliances run off the inverter: blender, food processor as well as a computer and a household stereo. The total possible daily load is approximately 10 MJ (2.7 kWh), while the actual load is estimated to be 6 MJ (1.7 kWh). Propane fires an instantaneous (demand) water heater and the range. Approximately 1,700 L of propane are required each year.The generator is run approximately six hours/week during November and December, and two hours/week through January and February, for a total of about 64 hours/year. There is no fridge, but a chest cooler is situated in the basement. The cooler sometimes requires ice to keep the temperature down during July and August.

The actual electrical use in this house is about 2,160 MJ (600 kWh) annually. The kWh equivalent of the propane appliances and water heater is 38,960 MJ (10,820 kWh), for a total of 41,120 MJ (11,420 kWh). The average annual lighting and appliance use for this vintage house in Nova Scotia is 24,500 MJ (6,810 kWh). Water heating accounts for another 24,500 MJ (6,810 kWh) for a total of 49,000 MJ (13,620 kWh). There is a difference of 7,880 MJ (2,190 kWh), a reduction of 16%, without a refrigerator. These figures do not include space heating.

Notes From Homeowner @ System Operation:
The house is primarily wired for DC, using a "modified buss bar". Large DC cables run up to the second floor through a concrete chase and travel to outlets on short runs of smaller wires. There are four AC runs throughout the house. Fuel usage should decrease as two new panels were installed this year, and two more will be installed next year, for a total system output of 720 W.

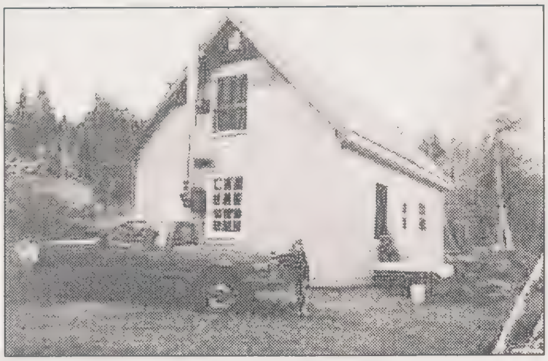
Homeowner's reasons for going off-grid:

PV installations are a part of the homeowner's business. PV is virtually maintenance free (requires someone to sweep snow off the array, turn the panels occasionally, and turn the inverter on or off), making it easy for non-technical members of the family to live with the system. The house began as a low-use seasonal dwelling and kept being added on to until it became a full-fledged dwelling.

Homeowner's observations on living off-grid and energy use patterns:

- Know what is "best" for your lighting fixtures: compact fluorescents have a lower lifespan and efficiency if they are cycled on and off too frequently. Halogen fixtures make excellent task lighting and are readily available at hardware/home centre stores. From the homeowners' travels in the U.S. and Mexico, they have found many more off-the-shelf options for lighting sources, such as inexpensive porcelain "pigtails" that convert a standard incandescent fixture to a halogen fixture (in Canada, halogen fixtures are available in a typical track lighting assembly). Site-built adapters can be made, but they are still more expensive than the "pigtails". Lighting is the number one issue/load after water pumping: difficult to find affordable, good, efficient equipment for either.
- Many AC appliances such as portable stereos, etc. are originally 12 VDC appliances fitted with adaptors. Cutting the adaptor out of the system turns the appliance back into DC, which can then be plugged directly into a wall socket wired for DC.
- Inverters are the weak link in any system: they can short out or overload. Newer models are better protected, and it may make more sense to have several smaller inverters throughout a house to carry smaller loads.

Energy Use Patterns in Off-Grid Houses – Case Study #9: Antigonish County, NS



House Description

A 6.1 x 9.1 m (20 x 30 ft.) one-storey house built on an open crawlspace. This house has been occupied by a family of four full-time since the fall of 1997. The house has reasonable solar access. An airtight woodstove provides space heating for the whole house (4 cords wood/year).

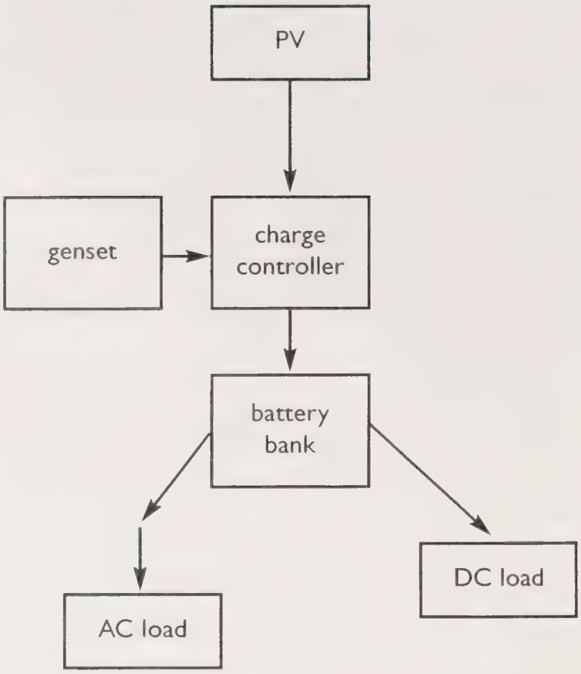
Thermal Envelope Summary
AC/H@50 Pa: 13.22
Walls: 3.5 RSI (R20)
Ceilings: RSI 3.5 (R20)
Floors: RSI 4.2 (R24)
Windows: single pane wood sliders w/storms
Doors: steel polyurethane core & wood

System Description

The power is supplied by a 420 W output PV array (4-105 W panels). Energy is stored in 8, 6 V golf cart batteries, wired to produce 12 VDC (880 Ah). All lighting is 12 V. A 250 W Trace Statpower inverter produces 120 VAC for the house. A 3.5 kW gas generator provides backup power. The system cost approximately $5,000 CAD.

System Performance

The load on the system includes 12 VDC lights, a water pump. The inverter powers a 13" TV, a VCR and a stereo. The total possible daily load is approximately 5 MJ (2 kWh), while the actual load is estimated to be 4 MJ (1 kWh). Water heat and cooking is provided by propane. Approximately 1,490 L of propane are required each year. The generator is run from five to 60 hours/month, for an estimated total of 365 hours/year. There is no fridge.



The actual electrical use in this house is about 1,340 MJ (370 kWh) annually. When the kWh equivalent for propane water heating is included, the total load is 24,140 MJ (6,710 kWh). The average annual lighting and appliance use for this vintage house in Nova Scotia is 24,500 MJ (6,810 kWh). Water heating accounts for a further 24,500 MJ (6,810 kWh) for a total of 49,000 MJ (13,610 kWh). There is a difference of 24,860 MJ (6,910 kWh), for a reduction of 51%, without a refrigerator. These figures do not include space heating.

Homeowners' reasons for going off-grid:

One of the owners is a seasonal worker, and wanted a house that would allow the family to have minimal annual costs, to be able to "coast" through the winter months when minimal income would be coming in. The cost of grid connection was a factor as well. Not wanting to give money to the utility company played a part in the decision.

Energy Use Patterns in Off-Grid Houses – Case Study #10: Belfast, PEI

House Description

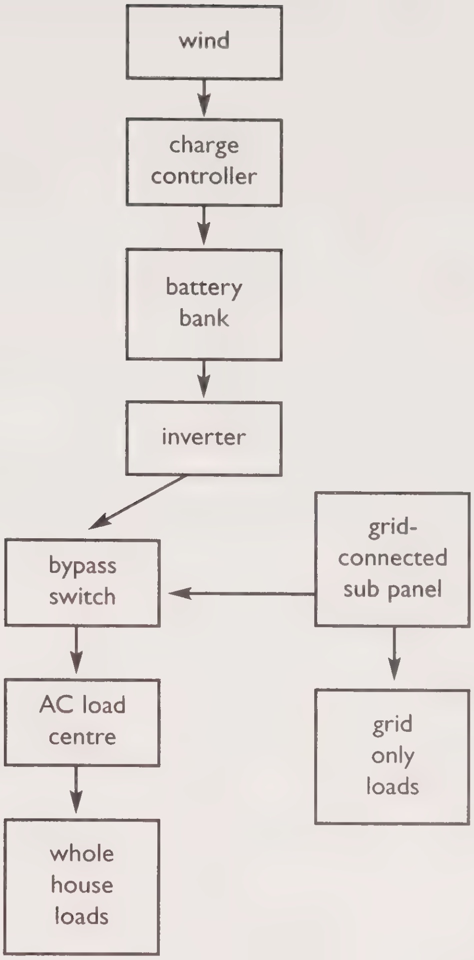
A 1 1/2 storey house built on a slab foundation. The main house is 7.3 x 9.7 m (24 x 32 ft.), the sunroom/office section is 4.9 x 7.0 m (16 x 23 ft.), and the workshop/studio section is 5.5 x 7.3 m (18 x 24 ft.), with 1.8 x 3.7 m (6 x 12 ft.) indoor wood storage area. The total heated area is 279 m^2 (3,000 sq.ft.). It was built as an affordable alternative to the PEI Advanced House Project (sponsored by NRCan). This house has been occupied by a family of five full-time since the fall of 1997 (currently three are full-time). The house has good solar access. An airtight woodstove provides space heating for the main section of the house (3 cords wood/year) and preheats the water. In-floor hydronic heat is installed in both main and upper floors, but only used in office and studio (upper floors). This alternative energy system is different from the other houses in the study, as it is connected to the grid. See below for details

Thermal Envelope Summary

AC/H@50 Pa: 2.19
Walls: 3.3 RSI
Ceilings: RSI 7.4
Floors: RSI 1.4 under slab
Windows: 3/8" space, low-E, argon casement and single hung
Doors: steel polyurethane core

System Description

Power is supplied by a World Power H900 wind generator, rated at 900 W output. Energy is stored in 4, Surrette "Big Red CS25" batteries, wired to produce 124 VDC (840 Ah). A 4,000 W Trace SW4024 inverter produces 120 VAC for the house. A grid-connected sub-panel provides backup power. The system cost approximately $18,000 CAD.



System Performance

The load on the system includes lights, a water pump, a fridge, two freezers, laptop computer w/printer, fax machine, portable stereo, TV/VCR unit, clothes washer, vacuum, iron, sewing machine, toaster and popcorn popper. The total possible daily load is approximately 29 MJ (8kWh), while the actual one is estimated to be 22 MJ (6 kWh), with the renewable energy system typically supplying 2 kWh per day. Water heat is provided seasonally by the water coil off the airtight stove. Cooking and the remaining hot water for the house is provided by propane. Approximately 600 L of propane are required each year. The grid connection is used to carry the house over times when the batteries are charging.

The actual electrical use in this house is about 7,810 MJ (2,170 kWh) annually. When the kWh equivalent of the propane appliances is included in this figure, the total is 21,380 MJ (5,940 kWh). The average annual lighting and appliance use for this vintage house in PEI is 24,500 MJ (6,810 kWh). Water heating accounts for another 24,500 MJ (6,810 kWh), for a total of 49,000 MJ (13,620 kWh). There is a difference of 27,620 MJ (7,670 kWh), for a reduction of 56%. These figures do not include space heating.

Notes From Homeowner @ System Operation:
It is important to note that the grid connection is not used to charge the batteries, rather it is used to carry the house through periods when the batteries are being recharged by the wind system. Although the wind generator is rated at 900 W, it acts more like a 600 W generator. A higher tower would result in better performance, but the homeowner feels that the wind unit is overrated. In 2001, the following changes will be made to the system: a new 1 kW-rated wind generator will be installed, as will a 1 kW PV system (16-75 W panels). This will bring the overall cost of the system to almost $30,000 CAD (less the sale of the original wind generator).

Homeowner's reasons for going off-grid:

The homeowner wanted the house to provide a demonstration of an effective renewable power system, to achieve energy self-sufficiency, and to reduce electrical use from non-renewable sources.

Homeowner's observations on living off-grid and energy use patterns:

- Hybrid systems are best suited to the Maritime region, as there is a good seasonal match between higher winter wind speeds and fewer sunlight hours.
- Wind generators typically give you more power per dollar invested.

Energy Use Patterns in Off-Grid Houses – Case Study #11: Keswick Ridge, NB

House Description

A 8.5 x 9.1 m (28 x 30 ft.) 1 1/2 storey house built on a vented crawlspace with an unheated 4.9 x 6.1 m (16 x 20 ft.) summer kitchen/storage area off the east face of the house. The house was built in 1994 and is occupied by a farming couple. This well-insulated timber-framed house was situated to maximize the passive solar gain available on the site. A high-mass combination wood heater with water jacket/cookstove assembly (2 cords hardwood/yr, one each for cooking and heating) on the main floor provides space and water heat as well as all cooking requirements.

Thermal Envelope Summary
AC/H@50 Pa: 5.36
Walls: 3.5 RSI (R20)
Ceilings: RSI 7.0 (R40)
Floors: not insulated
Windows: thermopane, single hung openers
Doors: steel polyurethane core

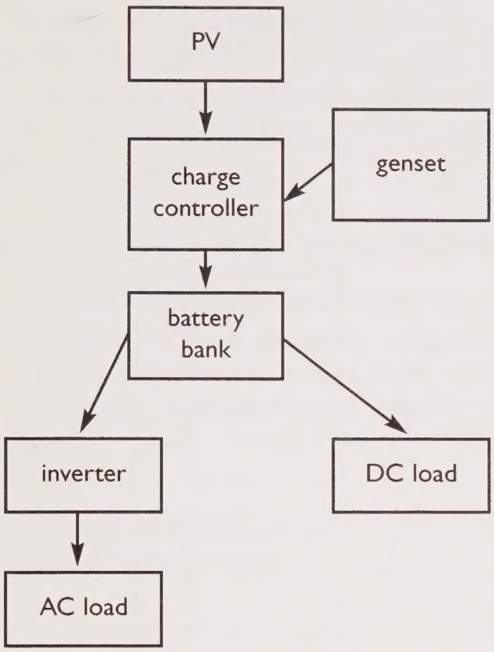
System Description

Power is supplied by a 333 W rated PV array (10 re-used "Arco" panels – 3=100W – slightly mirrored, probably operating at 90% of rated output). Energy is stored in 12, 6V Trojan T105 batteries, wired to produce 12 VDC (1,200 Ah). A Trace DR1512 modified sine wave inverter produces 120 VAC for the house. A diesel generator supplies backup power. The system costs $6,000 CAD.

System Performance

The load on the system includes lights, a water pump, a computer, an answering machine, turntable and stereo system, TV/VCR unit, blender, juicer and food processor in the kitchen and skilsaw, sander and chainsaw (summer use only). A 360 W block heater is used on the tractor three or

four times a year. The total possible daily load is approximately 7 MJ (2 kWh), while the actual load is estimated to be 3 MJ (1 kWh). Water heat is year-round off the heat coil within the heater/cookstove assembly.



The actual electrical use in this house is about 1,090 MJ (300 kWh) annually. The average annual lighting and appliance use for this vintage house in New Brunswick is 21,780 MJ (6,050 kWh) . There is a difference of 20,680 MJ (5,750 kWh), for a reduction of 94%. These figures do not include space or water heating.

Notes From Homeowner @ System Operation:
Generator is only used once or twice a year to equalize the batteries. Other than that, the PV array provides all electrical needs for this house.

Homeowners' reasons for going off-grid:

The remote location resulted in very high grid connection costs, however, this was not the motivating factor to be off-grid. The homeowners planned to be off-grid at any site they chose, because as environmentalists (that is, conservationists), they wanted to set an example of low energy use, especially in New Brunswick, with it's nuclear power generation plant.

Homeowners' observations on living off-grid and energy use patterns:

- This house doesn't have a fridge. A "California Cooler" is installed on an exterior wall of the kitchen. This assembly is typically a small locker that has a venting system that brings cool air from below ground. In this case, the cool air comes in from the root cellar under the summer kitchen (which has a dirt floor) into the bottom of the locker, which is thermally isolated from the heated part of the house. A second vent set high in the locker acts as a chimney to pull warm air out of the locker and keep the cool air passing over the stored food. This, plus a large walk-in pantry isolated from the heated portion of the house suffice to keep all stored food in good shape. This approach to food storage is probably more successful in a vegetarian household.

[1] *The estimated baseload figure for a house of this vintage is 24, 500 MJ (6,810 kWh). A reduction of 2,720 MJ (760 kWh) was made from the baseload to compensate for the absence of an electric range. 24, 500 – 2,720 = 21,780 MJ (6,050 kWh).*

Energy Use Patterns in Off-Grid Houses – Case Study #12: Eastern Shore, NS

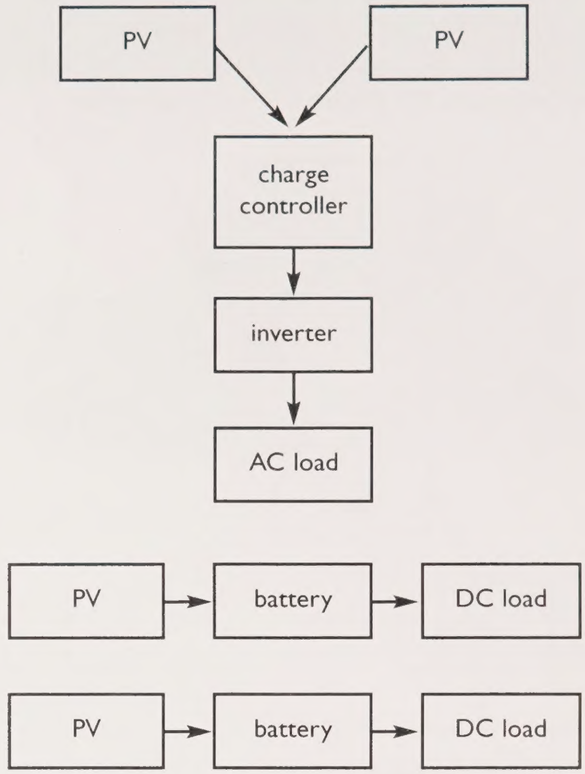
House Description

A 9.7 x 7.3 m (32 x 24 ft.) one-storey house built on an open crawlspace. The house was built in 1994 and is currently occupied by a single individual, but was previously inhabited by a family of four. The bulk of the glazing is to the south. The N and NW facade of the house are protected by trees, which reduce the rated output of the wind generator. An airtight stove (3 cords wood/yr, one softwood, two hardwood) on the main floor provides space heat.

Thermal Envelope Summary
AC/H@50 Pa: 3.72
Walls: 3.5 RSI (R20)
Ceilings: RSI 5.3 (R30)
Floors: 5.3 (R30)(cats have dislodged some of it)
Windows: thermopane casements
Doors: steel polyurethane core

System Description

Power is supplied by a 50 W PV panel and a 750 W (rated output) "Wind Baron" wind generator. Energy from these sources is stored in a 600 Ah battery bank and fed to a Trace 800 modified sine wave inverter for large loads. Two "mini-circuits" are also in place for small loads. Each of these consist of a 50 W PV panel connected to a 300 Ah battery bank feeding a 125 W Statpower modified sine wave inverter. The house is wired for 12 VDC and 120 VAC. A 1 kW gas generator supplied backup power until two years ago, it was sold when the load was reduced. The self-installed system cost $5,000 CAD.



System Performance

The 120 VAC load on the system includes lights, TV, battery charger, vacuum, laptop computer, and a cell phone. The 12 VDC load includes a marine water pump, rechargeable power tools, VCR and chest cooler. The total possible daily load is approximately 5.8 MJ (1.6 kWh), while the actual load is estimated to be 2.4 MJ (0.7 kWh). Propane is used for cooking. Water is heated on the stove. Approximately 240 L of propane is used annually.

The actual electrical use in this house is about 820 MJ (230 kWh) annually. The average annual lighting and appliance use for this vintage house in Nova Scotia is 24,500 MJ (6,810 kWh). When the kWh equivalent of the propane use is included, the total load is 6, 510 MJ (1,810 kWh). There is a difference of 17,990 MJ (5,000 kWh), a reduction of 73%. These figures do not include space or water heating (water is heated on the propane stove, but is used only for dishwashing and the occasional shower. The single occupant uses a "solar shower" bag for regular showering).

Notes From Homeowner @ System Operation:
The battery bank has partially failed due to being drained beyond the 50% level, and also because poor quality batteries were purchased. It is important to install the best quality batteries possible, with the longest life cycle noted. Extra cost on the batteries could possibly be counteracted by adhering to the 1% rule (from marine applications) which is: no charge controller is required for the battery bank if the bank is 100x bigger numerically than the 12 V output (in Amps) of your PV array.

Homeowners' reasons for going off-grid:

Bringing power to the remote location would have cost $30,000. Wanted to create an affordable, energy efficient off-grid house that would allow the owners to enjoy their lives without being in debt or having to work to keep up to operating costs.

Homeowners' observations on living off-grid and energy use patterns:

- Sales of both energy efficient compact fluorescent lighting and PV panels have increased dramatically over the last 10 years, but the price-point of both of these products has not dropped in a similar fashion. The manufacturers are in a sense pocketing the energy savings that consumers are gaining by using compact fluorescent fixtures and going off-grid.
- There are no thermal coil resistance appliances in this house, allowing the system to be designed cost-effectively.
- The biggest load in the house was high computer use, but the solitaire game was erased and a deck of cards bought. Now laptop (with 90 minutes of battery time) is used for no more than four hrs/day, and is hooked directly into the PV panel during the brightest part of the day. The cell phone is a steady four-hour load in the evenings, and is not plugged in during the day, to save both power use and money on phone bills.
- The chest cooler has to run full-time so it will be hooked up to its own 40 W collector on a tracker.

Project Manager: Don Fugler

Research Consultant: Shawna Henderson,
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